ATTRACTIVENESS OF LIQUID BAITS CONTAINING NATURAL AND ARTIFICIAL SWEETENERS TO WHITE-TAILED DEER

N. JAY BEAN, Department of Psychology, Vassar College, Poughkeepsie, NY 12601, USA
J. RUSSELL MASON, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Animal Damage Control, Denver Wildlife Research Center, and Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104, USA

Abstract: Baits are needed to deliver pharmaceutical products to free-ranging white-tailed deer (*Odocoileus virginianus*). For this reason, we studied various formulations, including 1 combination comprising apple odor, apple juice, water, salt, and glycerin. Because apple juice spoils rapidly in warm weather, we investigated whether sodium saccharin or cyclamate might be substituted for apple juice. Formulations we tested were (1) apple juice, water, glycerol, and salt; (2) saccharin, water, glycerol, and salt; and (3) cyclamate, water, glycerol, and salt. In addition, we either added an apple odor to each mixture or presented the odor in a scintillation vial attached to the dispenser. Deer visited and consumed more from dispensers containing apple juice ($P < 0.05$) than from those containing either artificial sweetener. Also, formulations containing apple odor as an ingredient were more attractive ($P < 0.05$) than those that did not. Artificial sweeteners are poor substitutes for apple juice in liquid bait formulations, and using preservatives like sodium benzoate may be more productive.

J. WILDL. MANAGE. 59(3):610–613

Key words: animal damage control, attractant, bait, New York, *Odocoileus virginianus*, taste, white-tailed deer.

The negative effects of foraging by white-tailed deer on forest regeneration and agriculture are of concern to managers and farmers (Conover and Decker 1991, Vecellio et al. 1994). In New Jersey, white-tailed deer damaged more than $20 million of various food and nonfood crops in 1990 (N.J. Farm Bur. 1990). Burgeoning deer populations also pose a growing threat to human and animal health and safety. Deer-automobile collisions have become common in many areas (Witmer and deCalesta 1992). Also, deer are important to breeding ticks (*Ixodes* spp.) that vector transmission of Lyme disease bacteria (Anderson 1988).

Nonlethal methods to reduce deer numbers and/or slow population growth in suburban and urban areas are being sought (Kirkpatrick and Turner 1985). Chemical and immunosterilants could become available by 1998 (Turner et al. 1990), but the problem of inoculating large numbers of deer remains. Silastic implants (e.g., Plotka and Seal 1989) and direct intramuscular injections (Harder and Peterle 1974) are not economical or efficient. Although oral vaccines would be inexpensive, efficient, and relatively easy to use, no bait formulations are available.

To provide a useable bait to deliver sterilants and other pharmaceutical products (e.g., Ivermectin for tick control), we have been studying attractiveness and palatability of solid (Mason et al. 1993) and liquid (Mason et al. 1995) formulations to free-ranging white-tailed deer. Liquid baits composed of apple extract, apple juice, water, salt, and glycerin are more attractive than solid baits (Mason et al. 1995). However, apple juice spoils in 24–48 hours during spring and early summer, when pharmaceutical delivery (e.g., delivery of tick medications) is desirable and when baits may be best accepted (W. J. McShea, Natl. Zool. Park Conserv. and Res. Cent., Front Royal, Va., and J. R. Mason, unpubl. data). Accordingly, we investigated whether sodium saccharin or cyclamate might be substituted for apple juice in liquid bait formulations.

Funding was provided by U.S. Department of Agriculture Cooperative Agreement 95-7407-0040-CA between the Monell Chemical Senses Center and the Denver Wildlife Research Center (DWRC). Procedures were approved by the DWRC and Monell Animal Care and Use committees.

STUDY AREA

We selected 3 25-ha sites near Poughkeepsie, New York. Each represented a different habitat type. One site was an old field with scattered apple trees (*Malus* spp.) and honeysuckle (*Lonicera japonica*); the second, a woodlot dominated by maple (*Acer* spp.); and the third, a

bottomland dominated by sweetgum (*Liquidambar styraciflua*) and sycamore (*Platanus occidentalis*). We regularly observed 10–20 deer at all sites 4 weeks prior to the experiment.

METHODS

Stimuli

We obtained apple essence (fragrance/flavoring) from M&M Fur Company (Bridgewater, S.D.). We purchased glycerol (CAS 56-81-5), sodium saccharin (CAS 81-07-2), sodium cyclamate (CAS 100-88-9), and sodium chloride (CAS 7647-14-5) from Sigma Chemical Company (St. Louis, Mo.). We bought generic apple juice.

We chose sodium saccharin as a candidate sweetener because it is one of few artificial sweeteners that mammals generally accept (Sclafani 1991) and sometimes prefer (Plice 1952, Jakinovich and Sugarman 1989). Also, mule deer (*O. hemionus*) prefer saccharin solutions to tapwater (Crawford and Church 1971). We chose sodium cyclamate because it enhances feed consumption by cattle (Plice 1952).

Procedure

Testing occurred between 1 March and 24 May 1994. We randomly selected 6 testing locations at each site. At each location, we suspended a liquid dispenser in a metal holder about 1 m aboveground. We positioned holders so that there were large trees behind them, and then mounted infrared motion detectors 1 m aboveground and 3–4 m away from each dispenser. Detectors were tuned so that they only recorded the time and date of visits by objects ≥60 cm in diameter within 0.5 m of the dispenser (Mason et al. 1993, Mason et al. 1995). Large trees behind dispensers blocked extraneous recordings. We recorded visit data and consumption from dispensers at 2-week intervals.

Liquid dispensers consisted of 1-L polyethylene bottles with a metal 15-mm diameter single-ball sipper tube attached. We filled bottles with liquid mixtures and placed them in a 32-cm high, 14-cm diameter section of PVC pipe. An end cap through which the sipper tube passed was permanently attached to the pipe. We taped a glass scintillation vial to each PVC pipe about 4 cm from the sipper tube (Mason et al. 1995). We inserted wicks (3 cm of braided cotton) through holes in the lids of these vials; 1.5 cm of the wick was exposed to the air for the release of volatile apple essence.

We evaluated 6 stimulus combinations (see below) over 12 weeks. We presented each combination for 2 weeks at a different test location. For each site, we randomly determined the order in which the test locations were used, as well as the order of stimulus presentation. All combinations contained 20% (vol/vol) glycerol, 60% distilled deionized water, and 2% sodium chloride. For 3 formulations (1–3), we presented apple extract (2% vol/vol, dissolved in propylene glycol) in the scintillation vial taped to the outside of the liquid dispenser. For the remaining 3 formulations (4–6), we incorporated apple extract into the solution (2% vol/vol). Within each apple extract condition, 1 combination contained 0.1 N sodium cyclamate (0.00201% vol/vol), 1 contained 0.1 N sodium saccharin (0.00205% vol/vol), and 1 contained 16–18% (vol/vol) apple juice (depending on whether apple extract was included as a mixture ingredient).

Analysis

Because we presumed that the same deer were sampling all stimulus combinations at each site, we assessed consumption and number of visits in 2-factor repeated measures analyses of variance (ANOVA) (Keppel 1973:423–456). Factors in these ANOVAs were apple extract (i.e., whether extract was included as a solution ingredient), and taste (apple juice vs. saccharin vs. cyclamate). We used Tukey's test to isolate differences among means.

RESULTS

Consumption

Consumption of solution was affected by apple extract ($F = 98.6$; 1, 5 df; $P < 0.001$) and taste ($F = 50.7$; 2, 10 df; $P < 0.001$). There was also an interaction between these terms ($F = 15.7$; 2, 10 df; $P < 0.001$), and we interpreted the analysis in terms of that highest order effect. Apple juice was preferred (Tukey's test, $P < 0.05$) to cyclamate or saccharin. Also, consumption of any solution was greater when apple extract was presented as a component of the mixture ($P < 0.05$). However, volatile apple extract as an ingredient increased consumption of the solution containing apple juice more ($P < 0.05$) than it did the consumption of solutions containing either saccharin or cyclamate (Fig. 1).

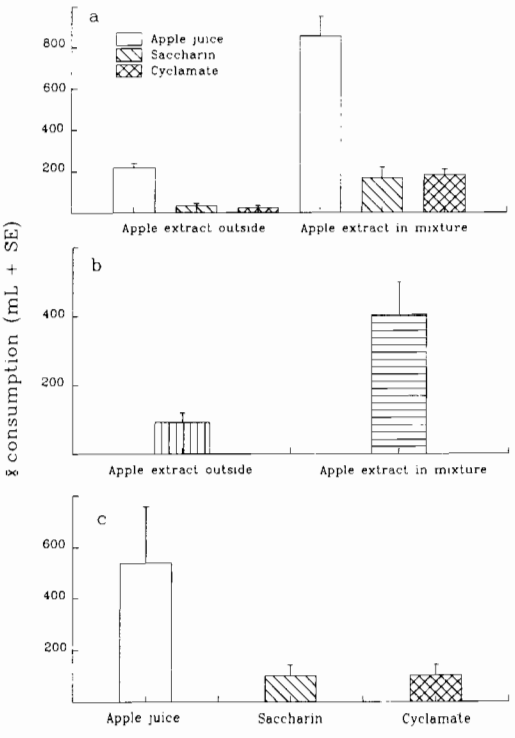

Fig. 1. (a) Mean consumption by white-tailed deer (near Poughkeepsie, N.Y., 1 Mar–24 May 1994) of apple juice mixture, saccharin mixture, or cyclamate mixture as a function of apple extract presentation. (b) Mean overall consumption as a function of apple extract presentation. (c) Mean overall consumption of apple juice mixture, saccharin mixture, or cyclamate mixture. Capped vertical bars represent standard errors of the means.

Visits

Visits were affected by apple extract (F = 13.5; 1, 5 df; $P < 0.01$) and taste (F = 44.0; 2, 10 df; $P < 0.001$), but there was no interaction between these terms (F = 0.09; 2, 10 df; $P > 0.25$). Visitation was greater (Tukey's test, $P < 0.05$) when apple extract was in the mixture and when apple juice rather than saccharin or cyclamate was present.

DISCUSSION

Even in the presence of apple essence, sodium cyclamate and sodium saccharin were not acceptable substitutes for apple juice. Perhaps deer detect unpalatable characteristics in these artificial sweeteners. However, quality of that unpleasant taste for deer is uncertain. Although saccharin has a characteristic metallic bitter aftertaste to humans, deer (and other herbivores) are generally indifferent to substances that humans characterize as bitter (Andelt et al. 1994). There is even some evidence that herbivores, including mule deer, prefer bitter tastes (Rice and Church 1974).

Unexpectedly, presentations of volatile apple extract as an ingredient of stimulus mixtures were more effective than presentations of extract in an attached vial. In previous experiments, extract was an effective lure, and it increased visits to scented locations (Mason et al. 1993). We anticipated that visits to locations might be similar, although consumption of bait might not be. Data suggest either that odor quality varied depending upon the method of extract presentation or that the deer discriminated the source of apple odor even though we presented scintillation vials close to sipper tubes.

MANAGEMENT IMPLICATIONS

We are cautious about extrapolating from this field experiment to other contexts. Nevertheless, a bait composed of apple extract, apple juice, water, salt, and glycerin appears to be an attractive vehicle for delivering sterilants or other chemicals (e.g., pesticides).

The task of identifying acceptable alternative sweeteners that extend the field usefulness of liquid deer baits remains. One potential source may be sweet substances derived from natural sources (e.g., various terpenoids and flavinoids; Kinghorn and Soejarto 1991). Alternatively, use of preservatives such as sodium benzoate may extend durability of existing bait formulations. Whether this is possible may hinge on other modifications of the formulation. Sodium benzoate is most effective in slightly acidic media (e.g., apple juice); in alkaline solutions (e.g., created by the use of sodium chloride), it is almost without preservative effects (e.g., Budivari et al. 1989:8531).

Other issues that remain unaddressed include the number, age, and sex of deer contacting bait, the frequency of contacts by individual deer, and the importance of season and geographic location (Schultz and Johnson 1992). Evidence from captive deer suggests that does and yearlings may be more likely to contact liquid dispensers than adult bucks (W. J. McShea and J. R. Mason, pers. obs.). Such differences have been reported for mule deer (Crawford and Church 1971, Rice and Church 1974). Also, captive deer ingest progressively greater amounts of bait as weather warms in spring (W. J. McShea and J. R. Mason, pers. obs.). This seasonal change in

acceptance is consistent with other evidence that free-ranging deer are more likely to consume dietary supplements (e.g., mineral licks) during spring and early summer (Weeks and Kirkpatrick 1976, Weeks 1978, Jones and Hanson 1985), and it may be more pronounced in southern (e.g., La.) than in northern states (Schultz and Johnson 1992).

LITERATURE CITED

ANDELT, W. F., K. P. BURNHAM, AND D. L. BAKER. 1994. Effectiveness of capsaicin and bitrex repellents for deterring browsing by captive mule deer. J. Wildl. Manage. 58:330–334.

ANDERSON, J. F. 1988. Mammalian and avian reservoirs for *Borrelia burgdorferi*. Pages 180–191 *in* J. L. Benach and E. M. Bosler, eds. Lyme disease and related disorders. Ann. N.Y. Acad. Sci., New York, N.Y.

BUDIVARI, S., M. J. O'NEIL, A. SMITH, AND P. E. HECKELMAN. 1989. The Merck index. Merck and Co., Rahway, N.J. 10100pp.

CONOVER, M. R., AND D. J. DECKER. 1991. Wildlife damage to crops: perceptions of agricultural and wildlife professionals in 1957 and 1987. Wildl. Soc. Bull. 19:46–52.

CRAWFORD, J. C., AND D. C. CHURCH. 1971. Response of black-tailed deer to various chemical taste stimuli. J. Wildl. Manage. 35:210–215.

HARDER, J. D., AND T. J. PETERLE. 1974. Effects of diethylstilbestrol on reproductive performance in white-tailed deer. J. Wildl. Manage. 38:183–196.

JAKINOVICH, W., AND D. SUGARMAN. 1989. Peripheral mechanisms of mammalian sweet taste. Pages 37–83 *in* R. H. Cagan, ed. Neural mechanisms in taste. CRC Press, Boca Raton, Fla.

JONES, R. L., AND H. C. HANSON. 1985. Mineral licks, geophagy, and biochemistry of North American ungulates. Univ. Iowa Press, Ames. 275pp.

KEPPEL, G. 1973. Design and analysis: a researcher's handbook. Prentice-Hall, Englewood Cliffs, N.J. 658pp.

KINGHORN, A. D., AND D. D. SOEJARTO. 1991. New highly sweet compounds from natural sources. Pages 14–27 *in* D. E. Walters, F. T. Orthoefer, and G. E. DuBois, eds. Sweeteners: discovery, molecular design, and chemoreception. Am. Chem. Soc., Washington, D.C.

KIRKPATRICK, J. F., AND J. W. TURNER. 1985. Chemical fertility control and wildlife management. BioScience 35:485–491.

MASON, J. R., N. J. BEAN, AND L. CLARK. 1993. Development of chemosensory attractants for white-tailed deer (*Odocoileus virginianus*). Crop Prot. 12:448–452.

———, ———, L. S. KATZ, AND H. HALES. 1995. Development of a bait for the oral delivery of pharmaceuticals to white-tailed deer (*Odocoileus virginianus*). Pages *in* T. J. Kreeger, ed. Contraception in wildlife. U.S. Gen. Publ. Off., Washington, D.C. In Press.

NEW JERSEY FARM BUREAU. 1990. White-tailed deer pest management. New Jersey Farm Bur., Trenton. 25pp.

PLICE, M. J. 1952. Sugar versus the intuitive choice of foods by livestock. J. Range Manage. 5:69–75.

PLOTKA, E. D., AND U. S. SEAL. 1989. Fertility control in female white-tailed deer. J. Wildl. Dis. 26:643–646.

RICE, P. R., AND D. C. CHURCH. 1974. Taste responses of deer to browse extracts, organic acids, and odors. J. Wildl. Manage. 38:830–836.

SCHULTZ, S. R., AND M. K. JOHNSON. 1992. Use of artificial mineral licks by white-tailed deer in Louisiana. J. Range Manage. 45:546–548.

SCLAFANI, A. 1991. The hedonics of sugar and starch. Pages 59–88 *in* R. C. Bolles, ed. The hedonics of taste. Lawrence Erlbaum Assoc., Hillsdale, N.J.

TURNER, J. W., I. K. M. LUI, AND J. F. KIRKPATRICK. 1990. Remotely delivered immunocontraception of captive white-tailed deer. Proc. Conf. Fert. Cont. Wildl., Univ. Melbourne Press, Aust. 50pp.

VECELLIO, G. M., R. H. YAHNER, AND G. L. STORM. 1994. Crop damage by deer at Gettysburg Park. Wildl. Soc. Bull. 22:89–93.

WEEKS, H. P. 1978. Characteristics of mineral licks and behavior of visiting white-tailed deer in southern Indiana. Am. Midl. Nat. 100:384–395.

———, AND C. M. KIRKPATRICK. 1976. Adaptations of white-tailed deer to naturally occurring sodium deficiencies. J. Wildl. Manage. 40:610–625.

WITMER, G. W., AND D. S. DECALESTA. 1992. The need and difficulty of bringing the Pennsylvania deer herd under control. Proc. East. Wildl. Damage Control Conf. 5:130–137.

Received 5 July 1994.
Accepted 17 December 1994.
Associate Editor: Avery.